Rainfall History (2000–2017) of Nature View Farm in the Eastern Cape, South Africa. Part I

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2018

'… an individual rather than a country is more likely to use physical violence in seeking recourse to a perceived water injustice' (Turton *et al.* in Turton, Ashton and Cloete 2003: 17).

Abstract

Annual rainfall (mm) figures for an 18-year period of Nature View Farm, overlooking the Kap River Nature Reserve (Eastern Cape, South Africa), were analysed and presented in a set of graphs to visually display total and average precipitation. The 18-year period was divided into two 9-year periods (P1 and P2) and despite pronounced annual rainfall variances (the highest rainfall of 321 (mm) above and the lowest annual rainfall of (187) mm below the 722 (mm) annual average, the total rainfall for P1 and P2 were the same. The Line of Best Fit for the 18-year period showed a declining rainfall trend over 18 years but could be 'corrected' within a short timeframe. Eighteen years are considered a 'short' analytical period in *longue durée* analytical terms and no climate change conclusions could be drawn. Environmental Humanities have much to contribute to rainfall history research.

Key words: Nature View Farm, Kap River Nature Reserve, Line of Best Fit, consecutive 2-year periods, near-future, far-future, extreme weather.

1. Introduction

The truism that 'water is life' became for former minister of water affairs and forestry, Ronnie Kasrils, an oversimplification in the sense that '[n]o civilization has ever succeeded without developing a sustainable water management strategy, and where this has failed, civilizations […] slowly faded away' (Kasrils in Turton and Henwood 2002: 9). And for Mikhail Gorbachev (in Turton and Henwood 2002: 7) 'Water can also be regarded as a source of universal shame, because three million children will die and millions more will become blind this year alone as a result of preventable water-borne diseases …'

Considering the growing phenomenon of ghost and near-abandoned *dorpies* (small towns), South Africa has its fair share of 'failed communities' where lack of water has been the prime driver for their continued inhabitability. This means that water should not be seen and treated as one variable amongst many of Cheap Nature (Moore 2015; Moore 2016). Instead, rainfall as an important water source is in many parts of the world a scarce resource. Even ancient Greece and Rome had sophisticated relationships between humans a nature (Thommen 2013). Whilst deserts are obvious examples, the city of Cape Town's much-publicized Day Zero water crisis during 2017 and the first quarter of 2018, gave rise to much official excuses and finger-pointing for the badly managed situation, whilst civil society mobilized collective action to avert a near-threatening water shortage disaster.

In addition, rainfall in this country, as in many other countries around the world, is a political issue at the heart of many contestations. Once rainwater enters rivers, then pumps, pipes and buckets, it enters the fray of the authoritative allocation of scarce resources debate: Whose water is it? Who should benefit from it? And who should control it? In South Africa, and particularly in ANC language under the guise of its 'National Democratic Revolution', 'emerging class interests conflict with those of poor people and communities' (Muller in Mc Lennan and Munslow 2009: 225).

In a cultural context of

> 'water and motorcars, or more correctly, who has access to what kind of water service and who drives what make of car, have become two defining features of post-apartheid society, reflecting the post-independence experience of East Africa where the emergence of the *Wabenzi* (the class who drove in Mercedes), came to characterise political development' (Muller in Mc Lennan and Munslow 2009: 225–226).

The two terms 'independence' in 'post-independence' and 'development' in 'political development', seem contradictions in terms. More helpful might have been the notion of the 'development of under-development' of the dependency theory (Hettne in Bottomore 1991: 137–139) of 30 years ago.

The above implies that the study of rainfall history is much more than 'just the numbers' thereof – where, when and how much it rains, or not. Interesting and necessary as an understanding of the hydro-politics of the immediate study area of this article might be, it does not fall in the scope of this investigation.

Instead, one of the requirements in researching (for another project) the enviro-history of the Kap River Nature Reserve (KRNR) that borders on Nature View Farm (NVF) (Fig. 1, Fig. 5 and Fig. 6), is to study its rainfall history. Rainfall determines to a large extent the development, stagnation or regression of the history of most enviro-historians' subject matter. This makes an understanding (in a narrow sense) of the *longue durée* recorded rainfall at NVF important because it also has some bearing on the KRNR. To underline this point: heavy rainfall over any part of NVF plays a significant role in governing the rainfall flood regime (Chakraborty *et al.* 2014: 6225) of the down-stream area and into the KRNR.

In 2004, researchers involved in 20th century extreme rainfall events in the United Kingdom, expressed similar views (Hand *et al*. 2004: 15). When one considers the lower Kap River area and its associated influence on the KRNR against the above, then it is no different. Of course, geo-specific conditions apply. In this regard, Dyson (2009: 269) wrote that 'different [rainfall] threshold values apply for different parts of the world'. With this view in mind, M.-C. Llasat (2001: 1386) agreed when she stated: 'thresholds vary considerably from one country to another, which means that it would be difficult to obtain a universal classification on the basis of the different thresholds'. The South African Weather Service (SAWS) (2017: 3) also dealt with this problem and held the same view. For the SAWS, many different institutions across the world currently house numerous different Climate Change Models 'each with its own formulation of atmospheric flow dynamics and physics. Significant differences might therefore occur in projection results, which can contribute to uncertainties in what the future might hold.' Therefore, some comments are later necessary about Heavy Rainfall Events (HRE) as they pertain to NVF and the KRNR.

The owners of NVF started recording the rainfall on their farm on a daily basis from as far back as 27 June 1999. To this day, the daily rainfall is still measured over a 24 h cycle from 08:00 to 08:00 the following day as is common practice (Nel 2008: 271). On the few occasions when the Van der Byls cannot record the rainfall on their farm, they are fortunate that someone else can take the readings for them (P. van der Byl 2018: pers. comm.). In so-doing they continue to ensure that a comprehensive record of reliable and valuable recorded rainfall data over the last almost 20 years, remains updated.

The value of their rainfall data makes robust multi-level sub-daily, daily, weekly, monthly, seasonal and annual analysis possible. At the other extreme, Izidine S. de Sousa Pinto (2015: iii) investigated mega-scale '*projected changes in extreme precipitation characteristics* (emphasis added) over southern Africa for the middle (2036-2065) and late [21st] century (2069-2098).' Incidentally, two years later the SAWS (2017: 3) used the 2036–2065 period as indicative of a near-future period and the years 2066–2095, as a far-future period.

But the scope for this study is minute in comparison to the above: it only attempts to assist in understanding *certain* aspects of the characteristics of the rainfall over the immediate area of NVF. Form such, it might also be possible to develop insight into HREs, defined as accumulated 50 mm rain or more per day, and rainstorms, defined as accumulated 25 mm rain or more for at least two consecutive days (Chakraborty *et al.* 2014: 6228), and their impact on the Kap River and the KRNR.

In October 2012 a small concrete low-water bridge (also referred to as causeway, see B in Fig. 1) over the lower part of the Kap River, that is situated less than a kilometer from its confluence with the Great Fish River, was washed away by a flood. Interestingly, this flood did not take place in the year with the highest ever recorded rainfall of 1 043 mm in 2011 of the study period (Table 1, Fig. 2, Fig. 4, Table 2, Fig. 7 and Fig. 11). The construction of a new replacement bridge is only scheduled to be completed by end August 2018. However, from the mid-July 2018, construction of this new bridge was temporarily terminated because the client defaulted in paying the contractor (Mr W. Schoeman: pers. comm. on 31 July 2018; Mr van Gerve: pers. comm. on 1 August 2018). Work resumed about three weeks later.

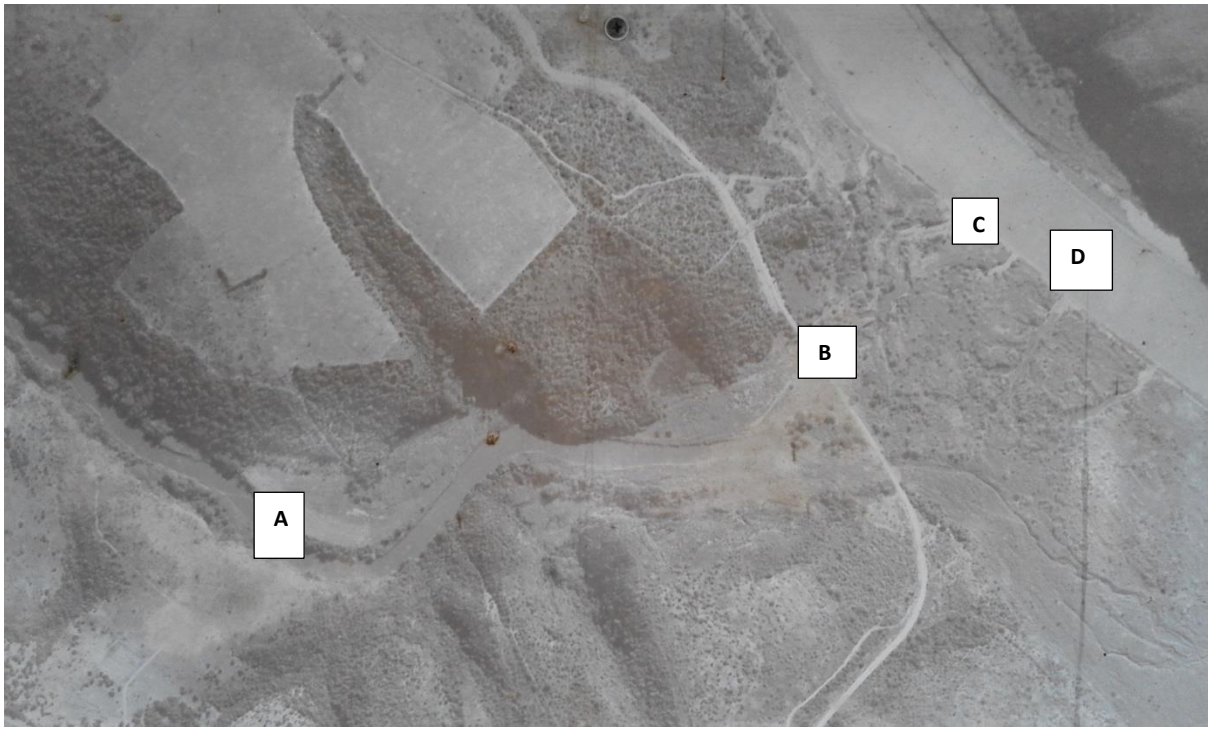

Figure 1. Aerial photograph (early 1980s) showing: A = Kap River; B = Bridge; C = Confluence and D = Great Fish River.

The purpose of this article is to make preliminary observations about the recorded rainfall data over a period of 18 years – from 1 January 2000 to 31 December 2017 – thus excluding the initial figures for 1999 from this analysis.

For practical reasons, the preference for the purposes herein was therefore to investigate 18 full calendar years, starting from 1 January 2000. In addition, no fraction of one millimeter of a recorded

year's rainfall was deemed necessary for inclusion in the calculations. Years with rainfall above the 90th percentile are regarded as wet years; those below the 20th percentile as dry years and in between as normal rainfall years (Fig. 4).

The value of the above is to understand the results of the Van der Byls' unique set of rainfall data for their farm in the first place, but also for the KRNR in general, because NVF only partially borders the KRNR on the west bank of the Kap River (Fig. 5 and Fig. 6). Because of the localized nature of the rainfall, it seems to have only a limited but still important impact on the entire lower KRNR. On 23 June 2018 the KR stopped flowing as a result of extended low rainfall over the catchment and started to dry out from its lower parts (Engelbrecht pers. observation 23 and 24 June 2018).

The loss of this low-water bridge in 2012 certainly impacted negatively on the economic activities of nearby farmers who are involved in the local pineapple industry. They have to transport their pineapple produce over increased distances in access of 50 km to the East London pine-apple processing plants. This has an adverse effect on their transport input costs.

Annual rainfall data supplied by Mr and Mrs Van der Byl for the 18-year study period is as follows (Table 1):

Table 1. Annual rainfall (mm) for the 18-year period at NVF.

Year		Total annual rainfall (mm)	
2000		719	
2001		903	
2002		661	
2003		759	
2004	**P1:** continuous period of 9 years	683	P1 total: **6 509**
2005		701	
2006		862	
2007		655	
2008		566	
2009		535	
2010		713	
2011		1 043	
2012		899	
2013	**P2:** continuous period of 9 years	587	P2 total: **6 502**
2014		682	
2015		888	
2016		548	
2017		607	
Total rainfall for 18-year period		**13 011**	

Despite the convenience and value of the Line of the Best Fit (least square line or trend line) in Figure 2, care should be taken not to make early predictions based strictly on the basis of this trend, since climate and weather hardly behaves in such strict mathematical confines. It remains however, practical and important for pro-active multi-level planning.

The Line of Best Fit (Fig. 2) indicates a decline of <70 mm over the study period.

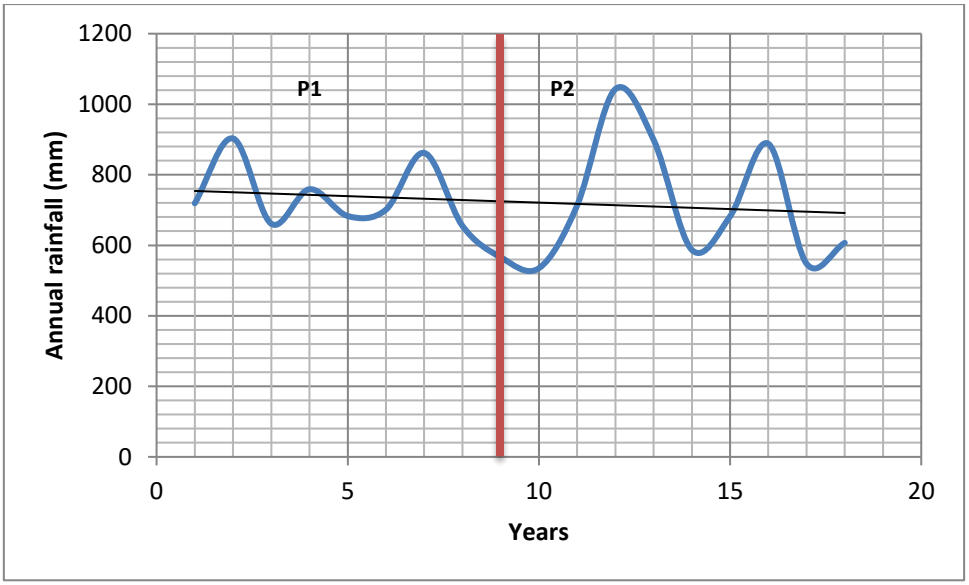

Figure 2. NVF's 18-year rainfall (mm) history with Line of Best Fit.

Similarly, Table 1 and Figure 9 indicate that over this 18-year period, the total rainfalls for the two nine-year periods (P1 and P2) differ by only 7 mm. In addition, Figure 2, Figure 3 and Figure 4 also show that the historical annual rainfall characteristics for the two periods are noticeably dissimilar.

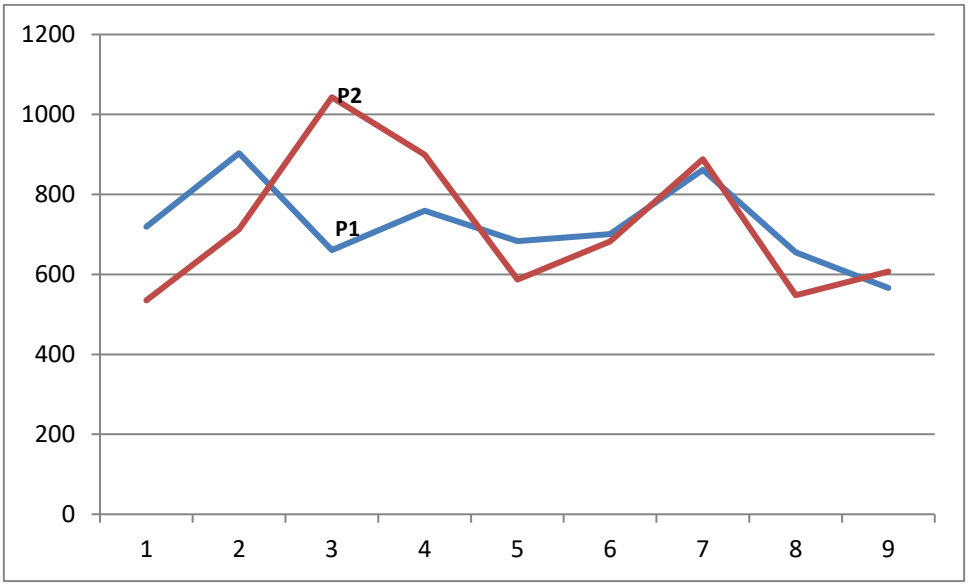

Figure 3. P1 and P2's nine year annual total annual rainfalls (mm) compared.

For the purposes herein, Figure 4 shows recorded annual rainfall above the 90th percentile, regarded as very wet years, whilst below the 20th percentile are considered as very dry years. Very dry periods are noticeably longer in duration than very wet periods. The SAWS (2018) also expresses the rainfall total change as the percentage change relative to a particular historical period.

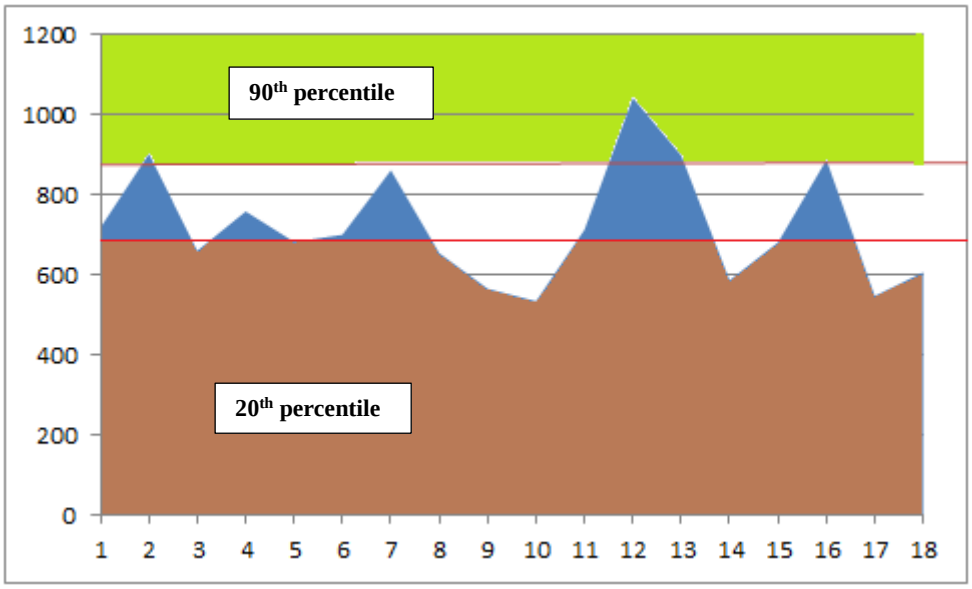

Figure 4. Distinction between 'wet' and 'dry' years over 18 years by applying two percentiles.

The rest of this article is divided as follows: the following section contains cryptic comments with reference to rainfall research in South Africa and elsewhere in the world. Of course, it is not intended to be comprehensive for this study. The intention is limited to give an impression of the scope and direction of research in the world.

Sections 3 deals with the location of NVF by using three maps: Figure 1, Figure 5 and Figure 6. The focus of section 4 is on the total and average rainfall figures for the study period. The last section makes comparisons in and between P1 and P2. The conclusion points to the most important observations within their contexts. It also suggests the future research needed.

2. Some comments pertaining to rainfall history research elsewhere in the world

Almost 15 years ago, McCarthy and Rubidge (2005: 215) wrote:

> 'Ever since multicellular life evolved [*c.* 3 500 mya], organisms within communities have been dependent on each other for their survival in relationships that involve mutual dependence. This interdependence has created an energy chain that is central to all ecosystems, today, and in the past.'

Much of this would not have been possible (amongst other variables) without rain. As the complexity of the theme that the 'increase in extreme weather due to climate change' (Pappenberger *et al.* 2013: 3) found in practically every piece of environmental research, grows, more and more researchers are showing an interest in the 'nature of trends in historical rainfall data in many different parts of the

world' (Hajani *et al*. 2014: 834). Needless to say, the use of historical rainfall data is nothing new, but the approach or uses thereof are. A few examples will suffice.

In the beginning of this century, María-Carmen Llasat (2001: 1383–1400) published an article that reported on the results of her study about *the nature of the process* that gives rise to rainfall on the basis of a distinction between precipitation of convective origin and precipitation of stratiform origin in Spain. One of the conclusions of this study was: 'It is thus possible to draw up a classification of the rainfall events in the light of their greater or lesser convective character' (Llasat (2001: 1399).

A.D. King (2014: 6035) studied *patterns* of 'monthly extreme rainfall variability in Australia' and found that 'extreme rainfall variability is more closely related to mean rainfall variability during austral summer than in winter. The 'El Nino-Southern Oscillation has the strongest association with warm-season extreme rainfall variability. Extreme rainfall variability in Australia can be related to remote drivers and local synoptic-scale patterns throughout the year.' For Yilmaz and Perera (2015) it is important to understand *effects that climate change and variability* have on extreme rainfall events. According to them, increasing trends for short storm durations for Victoria, Australia, were mostly statistically significant, while decreasing trends for long storm durations were statistically insignificant.

At about the same time Pinto published research about '*objective identification and ranking* [emphasis added] of extraordinary rainfall events for Northwest Italy […] using time series of annual precipitation maxima for 1938–2002 at over 200 stations'. She reported that Italy experience frequent occurrence of extreme rainfall events (Pinto *et al*. 2013: 2085).

In another study, Aguirre (2017) explains that their extreme rainfall research about the North-eastern US aims to '*identify specific types of storms* [emphasis added] that are more likely to lead to heavy rainfall. At the same time, we are trying to figure out what's different about those storms from ones that don't cause heavy rainfall'. North-east US is one of the regions in America with the largest increase in heavy rainfall events and it's the most economically developed and densely populated region of the country with a lot of infrastructure so an understanding an ability to predict should help to mitigate detrimental impact of such rainfall events.'

Uotila *et al.* (2007: 1) used *projections* from 15 climate models and two reanalysis products in order to project changes in the net precipitation over the Southern Ocean and Antartica during the 21st century. In this project they used from and compared three time periods: 1979–2000, 2046–2055 and 2091–2100. One of their conclusions that is based on the projected change in Antarctic, suggests that it is primarily due to thermodynamic changes, rather than circulation changes.

Recently Robertson *et al*. (2015: 2) observed that '[*f*]*loods* [in Alaska (Emphasis added)] are a key component of the flow regime of many rivers and a major structuring force of stream communities. Climate change is predicted to increase the frequency of extreme rainfall (i.e. return intervals > 100 years) leading to extensive flooding'.

Research about evidence of *climatic variation* in Siberia (Groisman *et al.* in Groisman and Gutman 2012: 59–109) studied three time periods: the last 10,000 years; the last millennium and thirdly, the last 130 years. They linked them to 21st century projections. Historically, climate variability of Siberia varied mainly between warmer and colder periods than that of the present. The last century became considerably warmer. Although the cold season precipitation north of 55°N increased, no rainfall increased over much of Siberia and the result is drier conditions in summer. Future climate projections point towards more temperature increases – more in the cold season and less in the warm season – and significant changes in the hydrological cycle. In addition, projected frequencies of various extreme events have increased recently and are projected to further increase in future.

About a decade ago, Dyson (2009: 627) studied *extreme rainfall events* over the Gauteng Province of South Africa and *distinguished between different extreme rainfall events* as follows: A significant rainfall event is defined when the average rainfall exceeds 10 mm, a heavy rainfall event when the average rainfall exceeds 15 mm and a very heavy rainfall event when the average rainfall exceeds 25 mm. To place *a lack of rain* in context, the South African Weather Service (2018) regards a deficit of 25% below normal rainfall, as generally a severe meteorological drought.

Only a year ago, J.A. du Plessis and B. Schloms (2017: 54) made the following observation in their conclusion:

> 'There are many factors indicating that climate change is indeed taking place. However, whether climate change has had an effect on the Western Cape seasonal rainfall patterns during the past 100 years is inconclusive'.

Lastly, an exciting recent publication is the South African Weather Service's *A Climate Change Reference Atlas*:

> 'The purpose of the South African Weather Service (SAWS) Climate Change Reference Atlas is therefore not only to provide a visual platform for *viewing* various climate projections of rainfall and temperature, but also to add to the number of projections that are already available in South Africa for *comparison*' (South African Weather Service 2017: 3) (Emphasis added).

The next section pays brief attention to the location of the NVF in relation to other farm land and the KRNR by making use of two maps (Fig. 5 and Fig. 6).

3. Location of Nature View Farm (33˚ 29' 09" S, 27˚ 05' 09" E)

NVF borders partially on the R72-road, approximately 24 km from Port Alfred to East London, and partially on the KRNR (Fig. 5 and Fig. 6) on the south-east coast of the Eastern Cape Province in South Africa.

The farm has an altitude of 70 m above sea level overlooking the lower part of the Kap River and some parts of the KRNR.

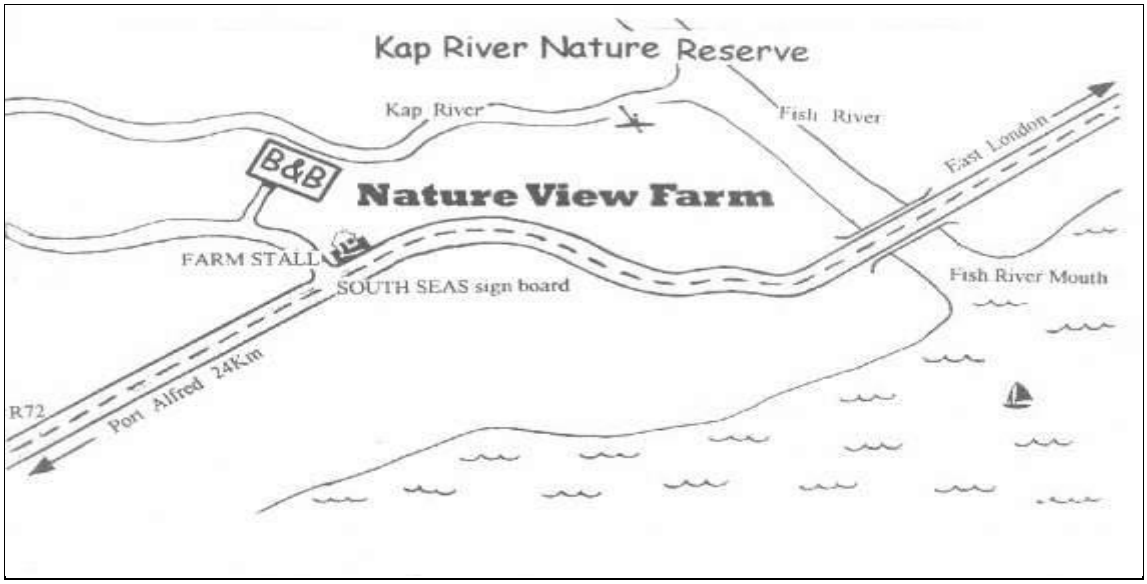

Figure 5. Map of NVF in relation to the R72-road, the Kap River and KRNR.

NVF is part of a piece of land (30 ha) that was also divided up into 40 smaller units of farm land each of about 30 ha in size (Fig. 6). According to Mr van der Byl (pers. comm. 17 July 2018) there is currently no economically active agribusiness conducted on units 3–12. Units 3, 9 and 11 have permanent residents whilst unit 6 has a foreman on a part time basis. The remaining units are absentee landowners.

From a Reserve Management file, marked Kap River Nature Reserve, Part 1-6, one finds under the heading Algoa R.S.C: Reserve Task Sheet, Title: Geology, Section 1.2.4, the description of the geology of the Cape Super Group rocks of the Witteberg and Bokkeveld Groups, to reach their most eastern reaches in the reserve. The rocks are of Ordovician and Devonian age whilst the cliffs of the Kap River Valley and the Fish River Point where they form a rocky ledge extending into the ocean, dating back to the Carboniferous to Triassic of between 250 and 360 mya (Rust in Lubke and de Moor 1998: 14; Maud in Lewis 2008: 3).

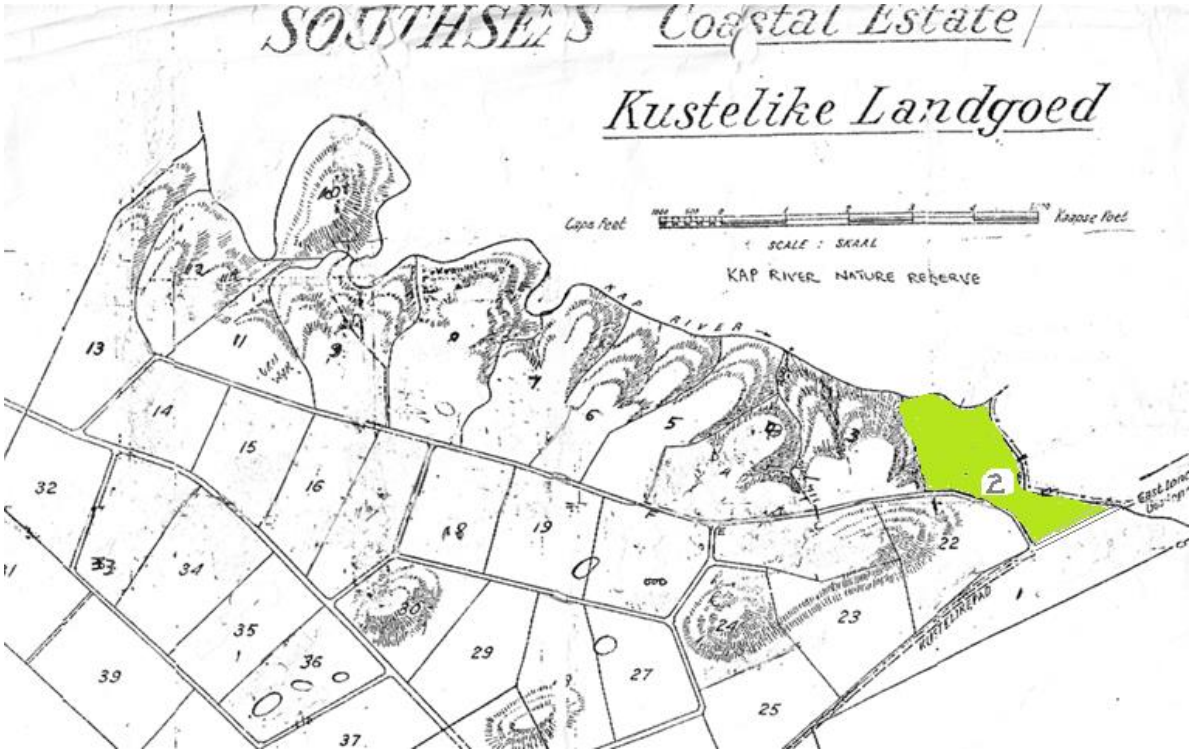

Figure 6. Map of NVF in relation to surrounding smaller units of farm land.

The vegetation varies from savanna and valley bushveld to riverine forest and Euhorbia thicket. The forest along the banks of the Kap River represent an example of forest that was not developed from warm temperate forest along stream banks. The farm borders on steep cliffs and has a rugged topography

4. Analysis of 18-year rainfall figures

4.1 Annual rainfall over 18 years

Table 2 summarizes the annual and monthly rainfall (mm) over 18 years at NVF. The total rainfall recorded for the 18 years was 13 011 mm. For analytical purposes, the 18-year period is divided into two nine-year periods as P1 and P2 respectively (Table 1, Fig. 2, Fig. 3, Table 2 and Fig. 7).

Table 2. Annual rainfall (mm) by month for an 18-year period as recorded at NVF.

P1	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec	Total Year
2000	149	36	184	52	27	7	2	15	58	35	147	10	719
2001	93	33	50	93	6	9	161	131	103	58	109	59	903
2002	47	9	14	61	7	19	113	126	116	29	73	48	661
2003	10	31	39	87	333	19	32	23	37	73	47	30	759
2004	95	29	108	32	9	4	55	10	84	44	48	167	683
2005	56	101	61	112	44	11	11	42	27	40	168	31	701
2006	46	52	34	54	117	48	19	245	59	69	54	67	862
2007	51	50	120	35	77	34	20	48	19	49	58	97	655
2008	66	92	43	51	28	39	14	32	22	38	53	90	566
2009	26	71	87	27	7	51	64	22	53	74	21	34	535
2010	67	27	22	167	3	98	37	41	12	139	27	72	713
2011	40	15	107	34	172	197	167	41	6	49	151	65	1043
2012	34	109	105	34	9	59	44	29	74	357	13	33	899
2013	26	58	81	53	37	6	40	18	6	107	65	92	587
2014	33	72	64	218	16	2	7	34	75	38	68	57	682
2015	48	27	27	256	19	121	152	54	39	45	95	6	888
2016	29	47	30	25	45	28	90	27	127	27	62	12	548
2017	28	51	36	27	36	2	13	68	63	74	148	62	607
P2	943	907	1209	1417	989	753	1038	1004	978	1342	1404	1029	13 011

The graph in Figure 7 (next page) also includes the 18-year annual average of 722 mm and repeats the division of the study period into two 9-year periods (being P1 and P2).

Whilst it is uncertain what the rainfall figures for the farm before 1999 might have been, the Line of Best Fit (Fig. 2) shows a gradual declining rainfall trend during the first 18 years of this century – although characterized by considerable comparative annual fluctuations (Table 1, Fig. 2, Fig. 3, Fig. 4, Table 2, Fig. 7 and Fig. 8).

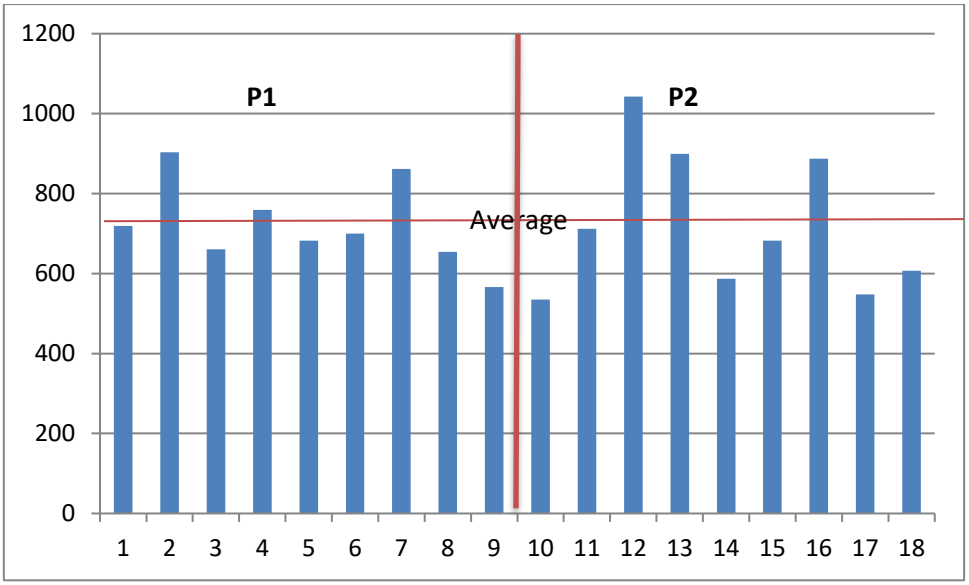

Figure 7. Annual rainfall for 18 years, indicating the 722 mm average per year.

Figure 8 shows the rainfall variability or deviation (above or below) from the 18-year average rainfall of 722 mm in absolute values.

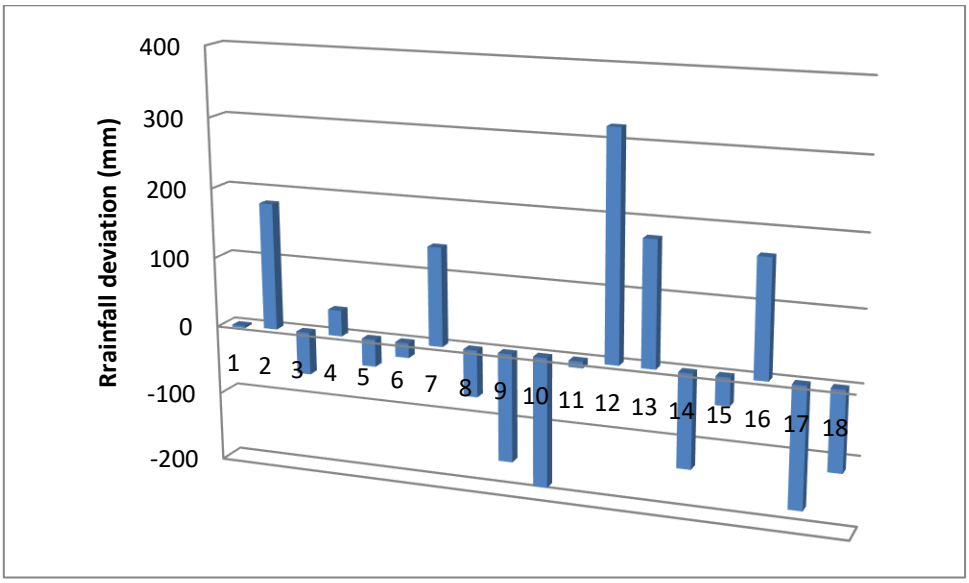

Figure 8. The annual deviation (mm) over 18 years of each value is the absolute value of the difference from the average of 722 mm.

Despite the above pronounced annual rainfall differences, there was only a marginal difference of seven mm in the total rainfall for P1 (6 509 mm) when compared to P2 (6 502 mm) as shown in Figure 9 and Table 1.

The implication is that the Line of Best Fit (Fig. 2) could be ‘re-adjusted’ through only as littles as one or two consecutive years with rainfall above the 722 mm average.

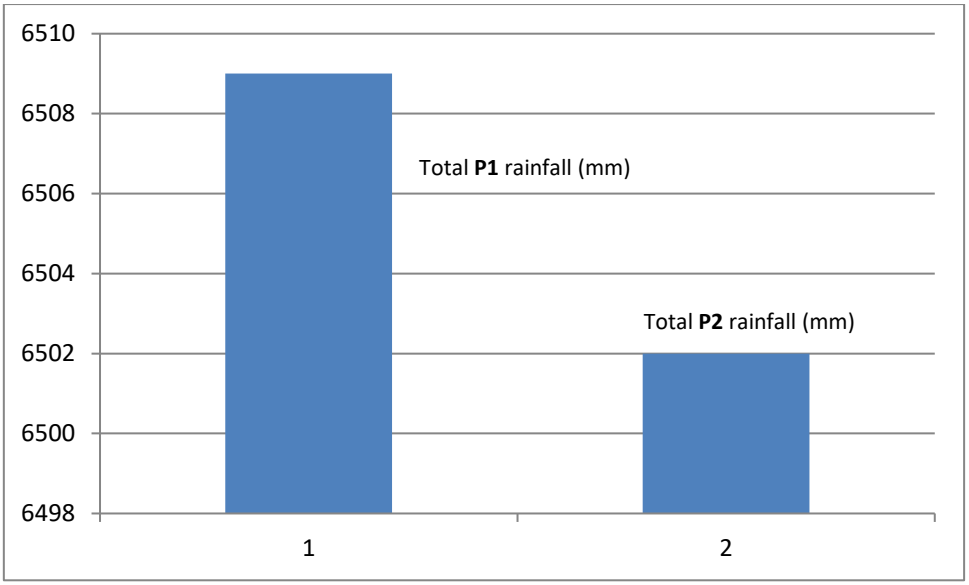

Figure 9. Total rainfall of P1 comparted to total rainfall of P2.

Table 1, Figure 2, Figure 3, Figure 4, Table 2, Figure 7, Figure 8 and Figure 11 also shows that the highest annual rainfall in 18 years, was 1 043 mm in 2011, the second highest of 903 mm was in 2001, the lowest of 535 mm in 2009, the second lowest of 548 mm was in 2016. The highest and lowest rainfall years are both located in P2. Figure 10 compares these:

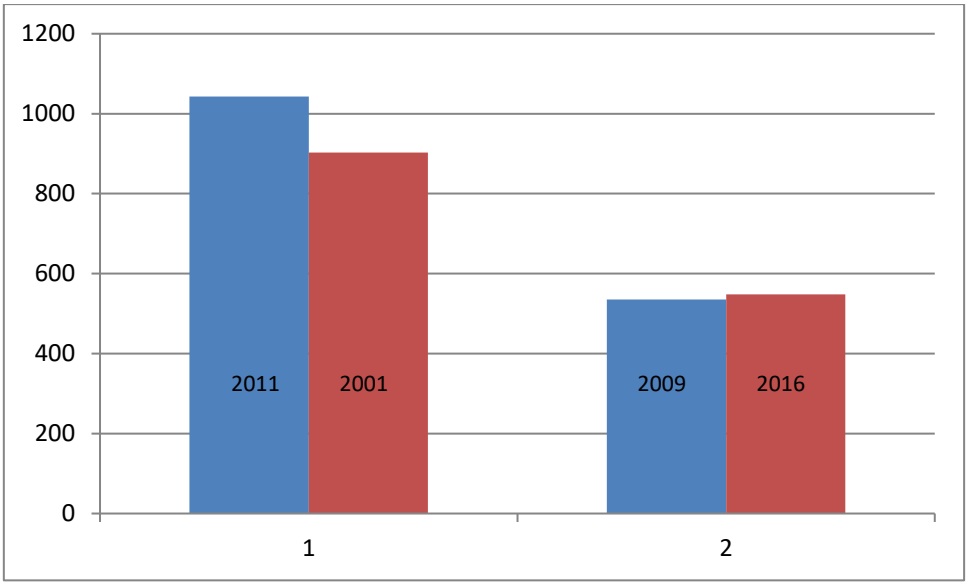

Figure 10. Comparison between highest, lowest and second highest and second lowest rainfalls (mm) in 18 years.
Key: 1 = Highest and second highest rainfalls (mm) in 18 years.
2 = Lowest and second lowest rainfalls (mm) in 18 years.

The difference of 508 mm between the highest (2011) and lowest (2009) annual rainfalls during the 18-year period is compared in Figure 10. The highest (2011) and lowest (2009) rainfall years, are split by only one year between them, 2010,but between the year with the second highest (2001) and second lowest rainfalls (2016), 14 years lapsed as shown in Figure 11.

The difference of 355 mm between the second highest and second lowest annual rainfall during the 18-year period is also compared in Figure 10.

In percentage terms, the year with highest rainfall (mm) in 18 years was 19,4% higher than the year with the lowest rainfall of the period. The year with the second highest rainfall had 16,4% higher rainfall that the year with the second lowest recorded rainfall.

4.2 Average annual rainfall for the 18-year period

As already mentioned a few times, the average annual rainfall for the 18-year period was 722 mm (Fig. 7 and Fig. 11).

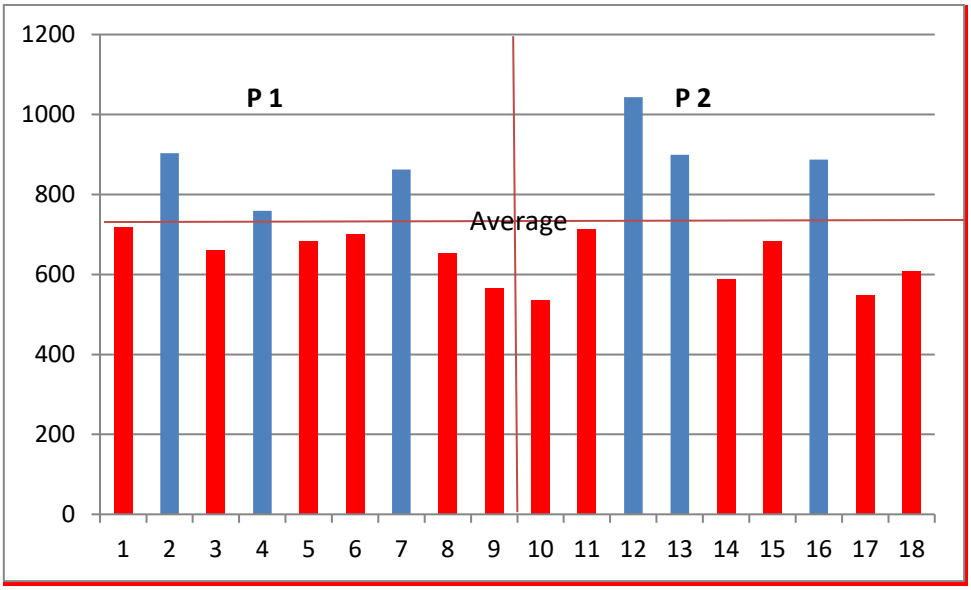

Figure 11. The 12 years with below average rainfall (red) of 722 mm compared to the full 18-years.

About 33% of the time, or six years (in blue) of the 18 years, had rainfall above the average annual rainfall of 722 mm, and 66% of the time, or 12 years (in red) of the 18 years, had rainfall below the average annual rainfall of 722 mm (Fig. 7 and Fig. 11).

These two percentages of above and below the 18-year period's average of 722 mm are compared in the following pie chart (Fig. 12):

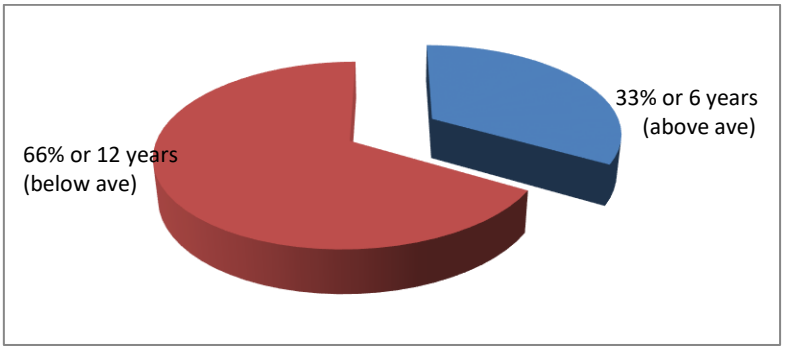

Figure 12. Percentage of years with above or below 722 mm average rainfall of the study period.

Most of the above graphs show that the annual fluctuations in rainfall in the immediate vicinity of NVF are often significant (Fig. 11, Fig. 8, Fig. 7, Table 2, Fig. 4, Fig. 3, Fig. 2 and Table 1).

4.3 Average annual rainfall (mm) levels split between above or below the 18-year period's average of 722 mm

4.3.1 Average annual rainfall (mm) levels of six years with *above* the 18-year period's average

A total of six years (three years in P1 and three years in P2) had an average annual rainfall level above the average of the 18-year period's 722 mm (Fig. 7, Fig. 8, Fig. 11, Fig. 12 and Fig. 13).

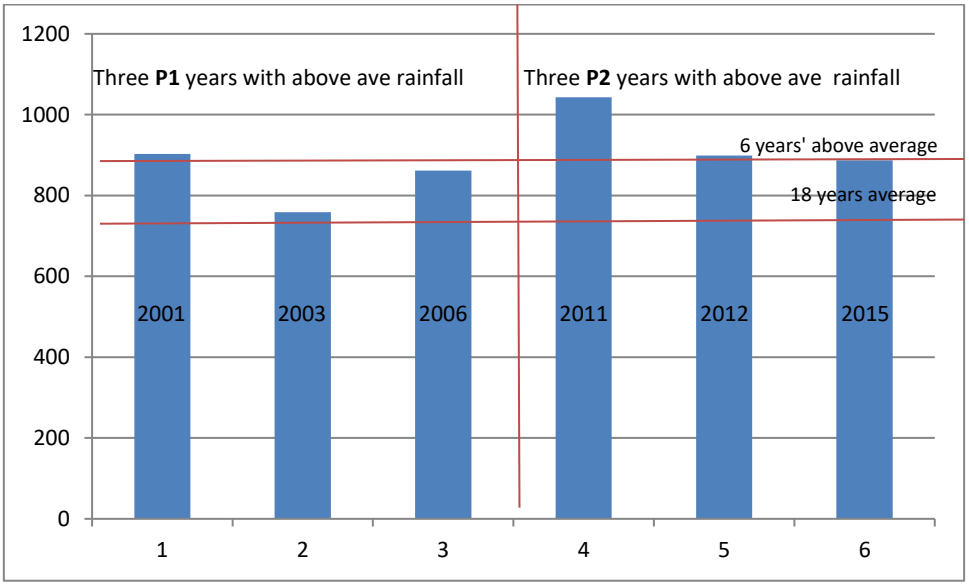

Figure 13. Annual rainfall (mm) levels of six years with above the 18-year period's average.

The average rainfall for these six years with above the 18-year average, is 892 mm (Fig. 13). This is difference of 170 mm or 12,3% is compared as follows in Figure 14:

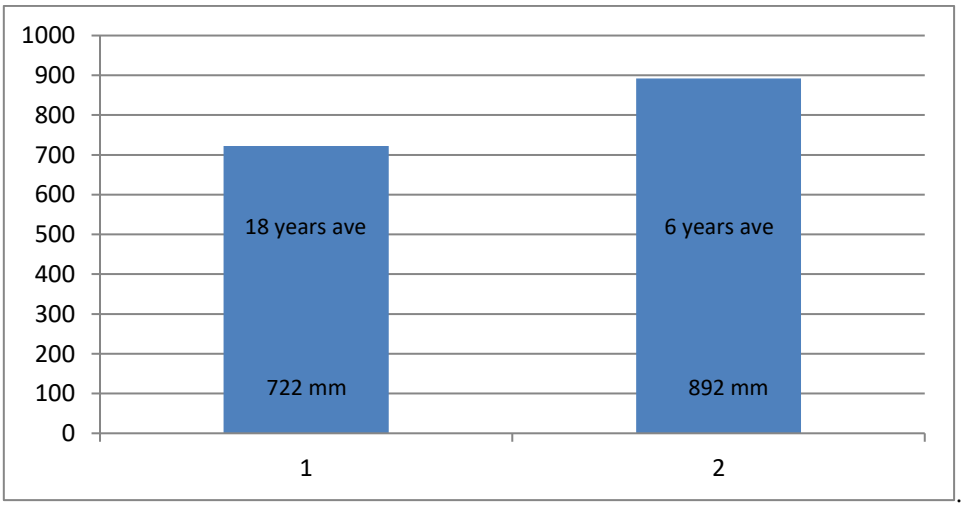

Figure 14. The difference of 170 mm rainfall of six years above average rainfall (mm) compared to the 18 years average of 722 mm..

4.3.2 Average annual rainfall (mm) levels of 12 years with *below* the 18-year period's average

The data for 12 years with below average rainfall (Fig. 7, Fig. 8, Fig. 11 and Fig. 12) is different. Twice as many years (six years in P1 and six years in P2) in comparison to those with above 722 mm, had below the study period's average rainfall of 722 mm.

The average annual rainfall level of the 12 years with below average rainfall was 637 mm per annum (Fig. 15):

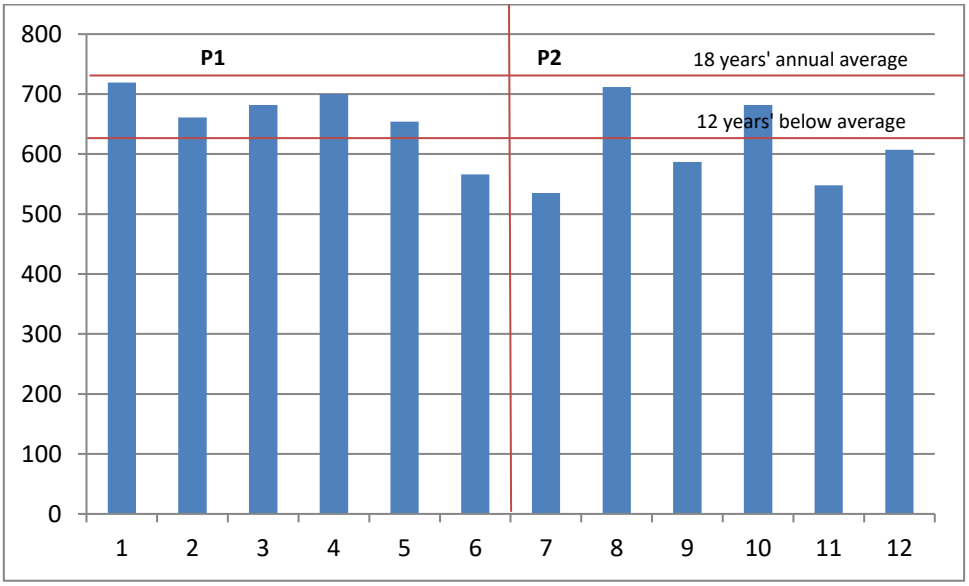

Figure 15. The 12 years with below average rainfall (mm) comparted to the 18-year average.

Key: 1= 2000 5 = 2007 9 = 2013
2 = 2002 6 = 2008 10 = 2014
3 = 2004 7 = 2009 11 = 2016
4 = 2005 8 = 2010 12 = 2017

This is on average 85 mm or 11% per year lower that the annual 722 mm average for the 18 years. The difference between these averages is compared below in Figure 16:

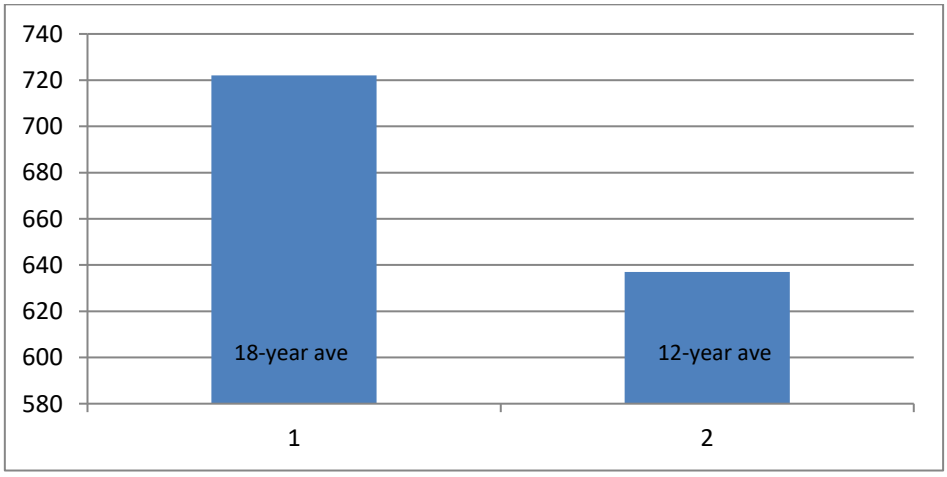

Figure 16. The 18-year average rainfall compared to the 12 years with below average rainfall.

The average of 85 mm rain below the 18-year period's average of 170 mm above the 722 mm 18-year period's average compares as follows in Figure 17:

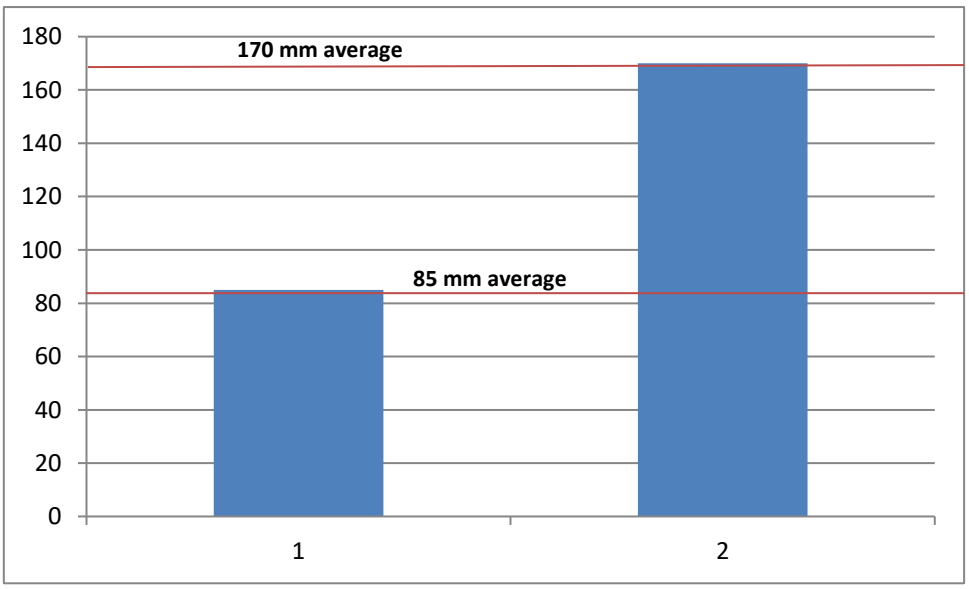

Figure 17. The difference in above average rainfall (for 12 years) compared to below average rainfall (for 6 years) (mm).

Therefore: the *below* average rainfall for 18 years (Fig. 17) is about half of *above* the average for the same period in terms of volume (mm), but the *below duration* lasts twice as long in terms time – 12 years vs 6 years (Fig. 11 and Fig. 12).

4.4 Average annual rainfall for the six years immediately *after* the year with highest rainfall

The average annual rainfall for the six years in P2 immediately following 2011 (Fig. 11) – the year with the highest rainfall in 18 years – were 701 mm per annum as per Figure 18:

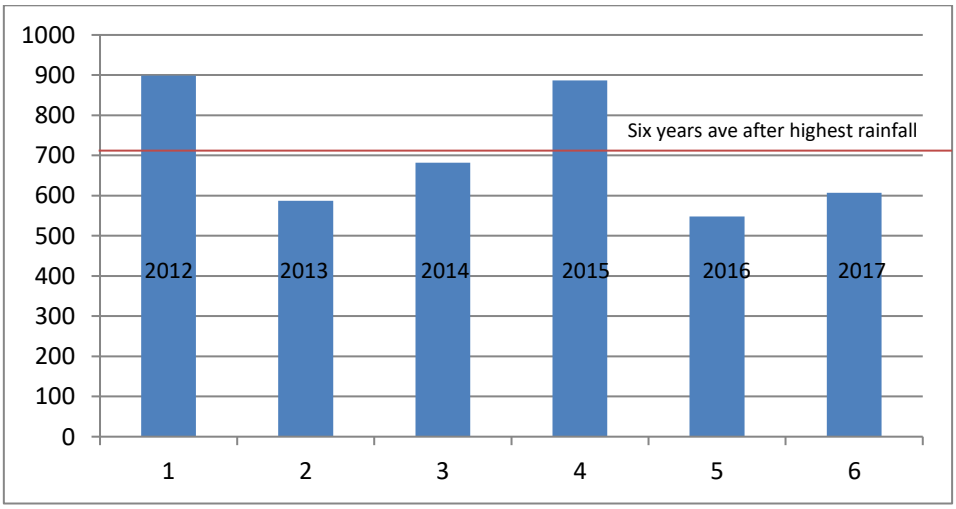

Figure 18. Six year's average rainfall (mm) after highest recorded annual rainfall (mm) in P2.

This means that for 33% of the time (or six years out of the 18-year period), NVF had on average 21 mm rain per year less than the average rainfall for 18 years (722 mm). The difference is presented as follows (Fig. 19):

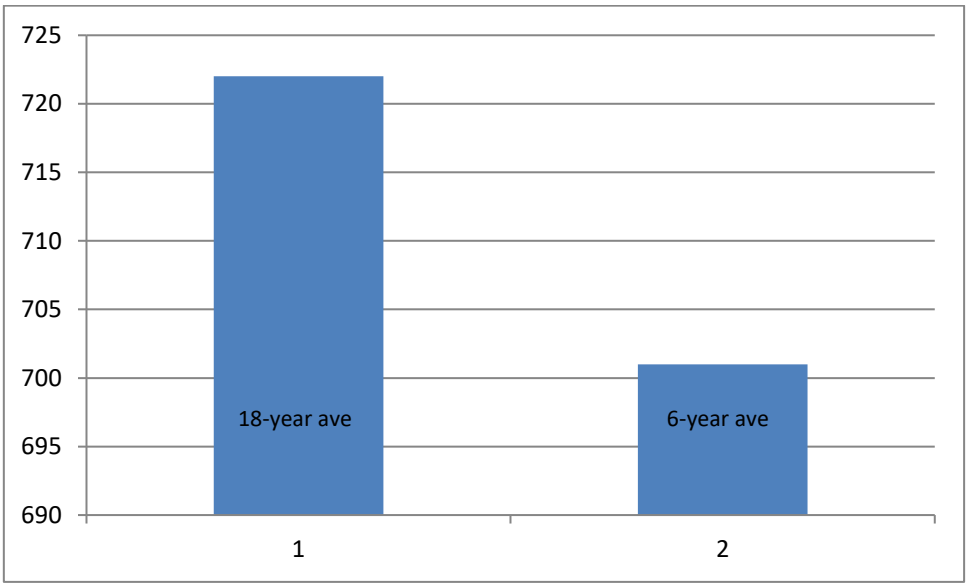

Figure 19. Average rainfall for six years following the year with highest rainfall, compared to 18 years' average of 722 mm.

In fact, only two of the six years (that is excluding the year with the highest rainfall in 18 years) in P2 (2012 and 2015) had rainfall above the 722 mm level (Fig. 7, Fig. 11 and Fig. 18).

A further noticeable characteristic of the six years immediately after 2011 is the steady declining rainfall trend over time as shown by the Line of Best Fit for the period 2012–2017 in Figure 20:

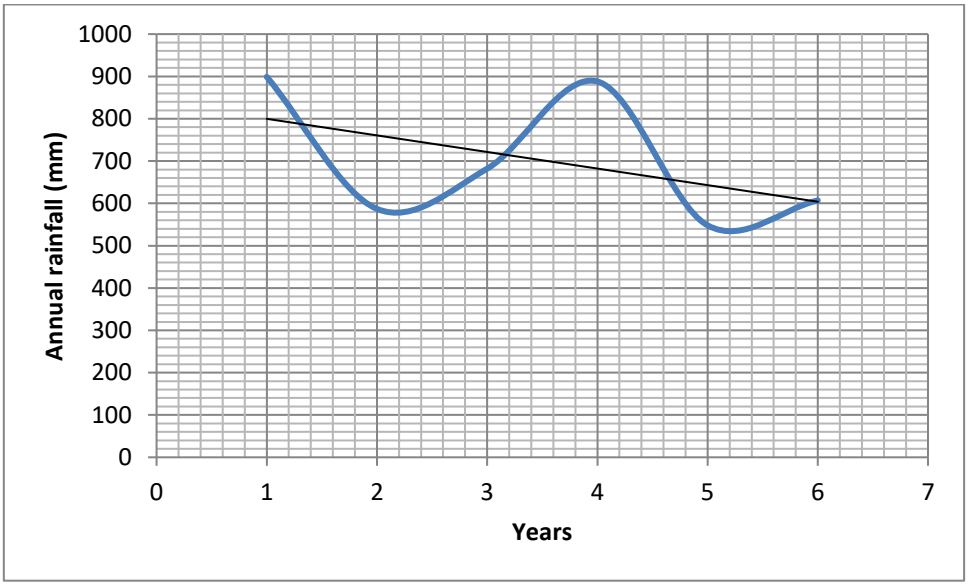

Figure 20. Steady declining trend in rainfall (mm) over six years following year with highest (2011) rainfall (mm) in 18 years.
Key: 1 = 2012
6 = 2017

This Line of Best Fit (Fig. 20) is more pronounced for the six years following the year with the highest rainfall than the Line of Best Fit for the full P2 (Fig. 21) despite the fact that in Figure 20, the year with the highest rainfall (2011), has been excluded from the calculations for Figure 20.

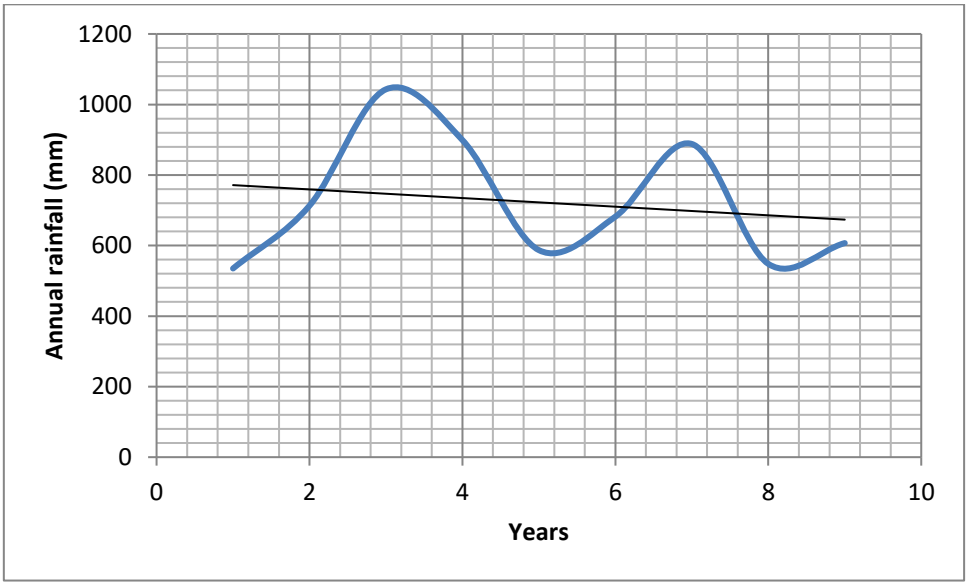

Figure 21. Line of Best Fit for P2.

The year with the highest rainfall (2011 with 1 043 mm) was followed by one year (2012) with 899 mm which is 15% less rainfall that in 2011 (Table 1, Fig. 3, Fig. 4, Table 2, Fig. 7, Fig. 8 and Fig. 11). This means that 2012's rainfall (899 mm) was still 177 mm above the 18-year period's average of 722 mm (Fig. 7, Fig. 11 and Fig. 13). This is very close when compared to P2's average of 701 mm (Fig. 22).

Then followed two consecutive years (2013 and 2014) with below the 722 mm of the 18-year period's average (Fig. 25). The total rainfall (mm) for 2013 and 2014 was 1 269 mm and its average was 634,5 mm rainfall per year. This average was 6,3% or 66 mm below the average of 701 mm for P2, and 88 mm less or 12,1% below the 18-year period's average of 722 mm (Fig. 18).

The following year, 2015's rainfall, was 888 mm, or 166 mm (or 18,6%) higher than the 18-year period's average of 722 mm (Fig. 18 and Fig. 22). It was also the first year in three years with above 722 mm. The average rainfall for P2 was 701 mm and therefore 2015's rainfall was well above that, with 21,8%.

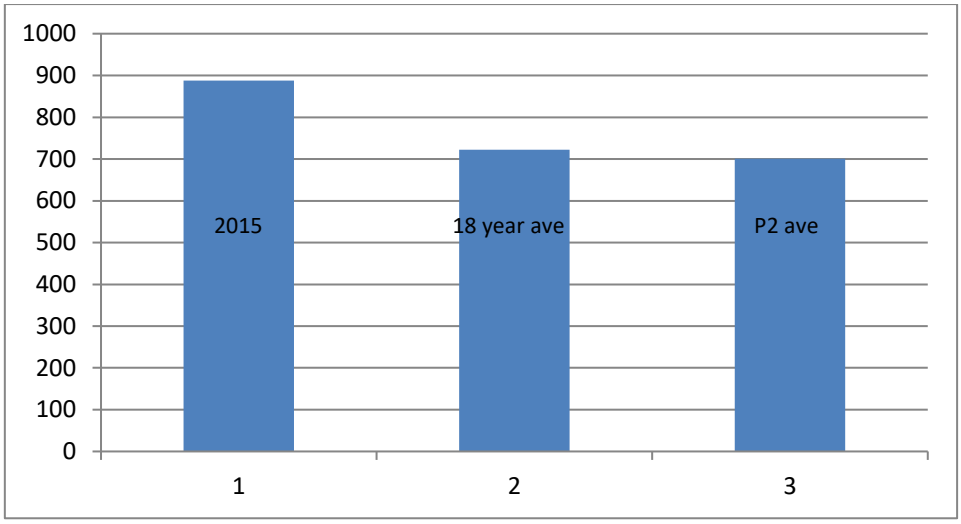

Figure 22. Rainfall (mm) of 2015 compared to 18-year average and P2's average rainfall.

It is interesting to see how little difference there is when 2015's rainfall (mm) is compared to that of 2001, 2006 and 2012 of more than a decade earlier (Fig. 23):

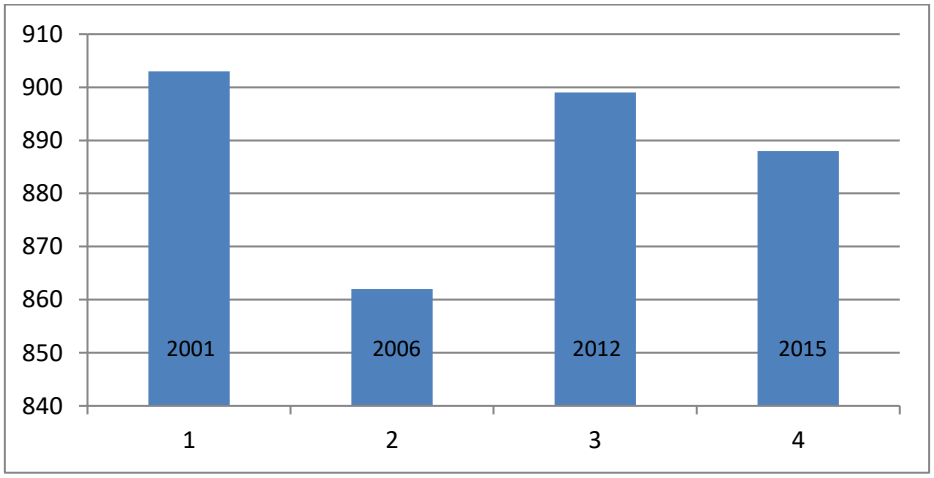

Figure 23. Annual rainfall (mm) of 2015 compared to 2001, 2006 and 2012.

Figure 24 compares the total rainfall for a second consecutive 2-year rainfall period – 2016 and 2017 to that of the first consecutive 2-year period (2013 and 2014). This second consecutive 2-year period's total rainfall was 1 155 mm and its average was 577,5 mm. The total rainfall of this consecutive 2-year period was 114 mm less than the total rainfall of 1 269 mm for the first consecutive 2-year period.

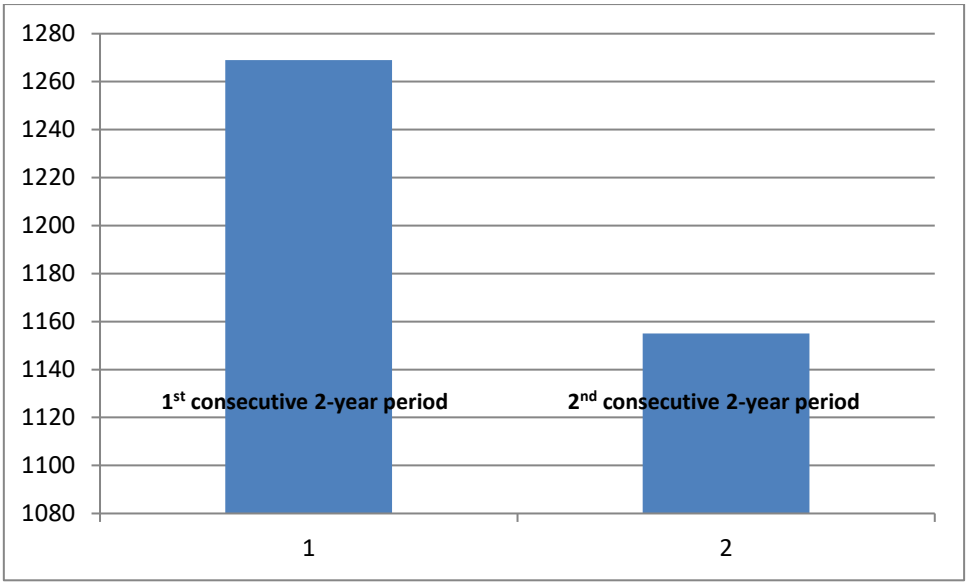

Figure 24. Total rainfall (mm) for first and second consecutive 2-year rainfall periods compared.

The difference in average rainfall (mm) between the two consecutive 2-year periods was 57 mm as shown in Figure 25:

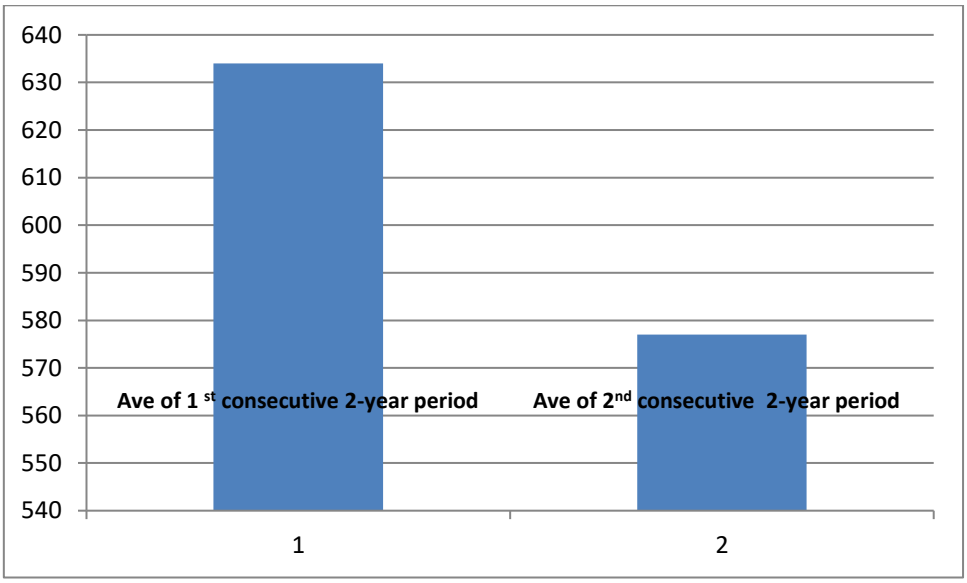

Figure 25. A comparison between 1st consecutive 2-year period's average rainfall (mm) and that of the 2ndconsecutive 2-year period's average rainfall (mm).

The 3rd and last consecutive 2-year period in P2, is 2009 and 2010. These two years preceded the year with the highest rainfall (2011).

The total rainfall for this 3rd consecutive 2-year period is 1 248 (mm) and the average is 624 (mm). When the three consecutive 2-year periods in P2 are compared in total rainfall (mm) terms as in Figure 26, as well as in average rainfall (mm) terms as in Figure 27, the two graphs are as follows:

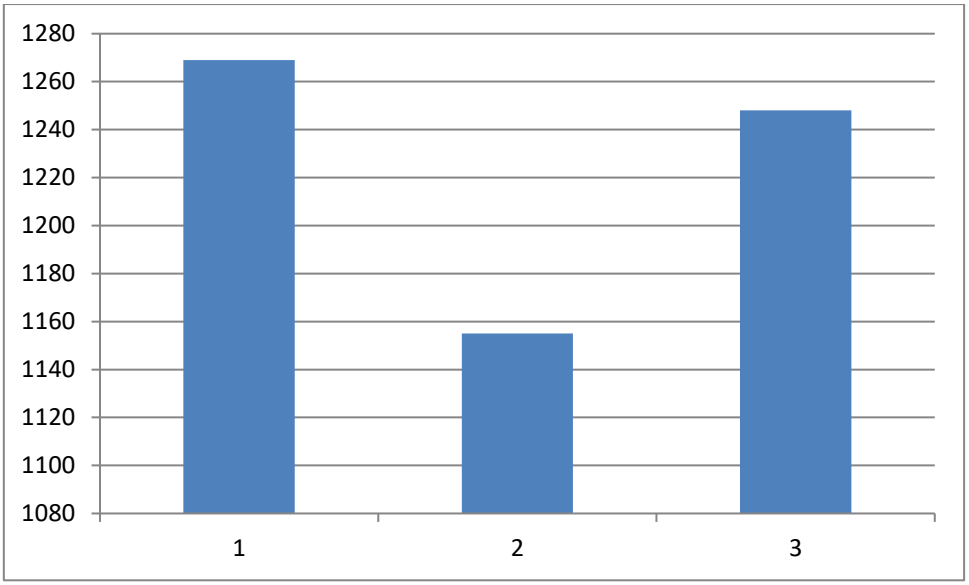

Figure 26. A comparison of the total rainfall (mm) for three consecutive 2-year periods in P2.
Key: 1 = 1st consecutive 2-year period (2013 and 2014)
2 = 2nd consecutive 2-year period (2016 and 2017)
3 = 3rd consecutive 2-year period (2009 and 2010)

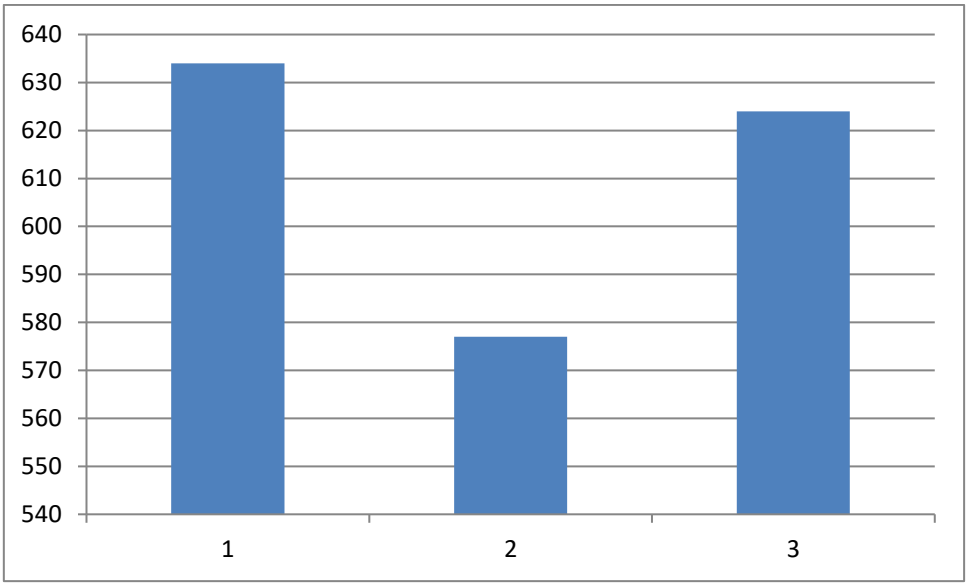

Figure 27. A comparison of the average rainfall (mm) for three consecutive 2-year periods in P2.
Key: 1 = 1st consecutive 2-year period (2013 and 2014)
2 = 2nd consecutive 2-year period (2016 and 2017)
3 = 3rd consecutive 2-year period (2009 and 2010)

Despite the fact that the three consecutive 2-year periods in P2 all had rainfall (mm) in real and average terms of below the 722 mm average, they also have the following in common: the second of the two years in the respective three consecutive 2-year periods (2010, 2014 and 2017) were all preceded by a year of less rainfall (in 2009, 2013 and 2016) (Table 1 and Fig. 11). But this happened only once in 2004 and 2005 in P1.

4.5 Average annual rainfall for the 11 years immediately *before* the year with highest rainfall

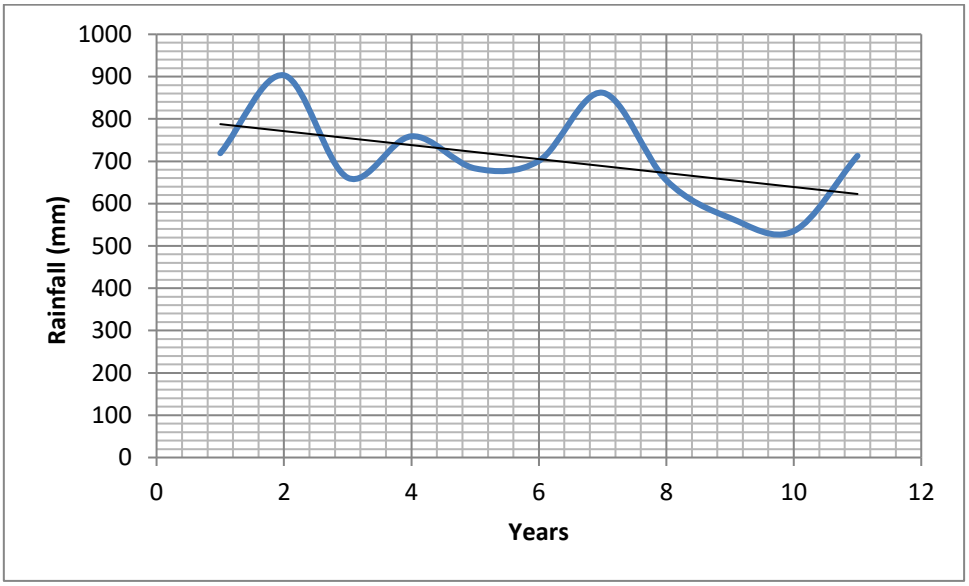

Figure 28. The average rainfall (mm) and line of best Fit for the 11 years before 2011.

The average rainfall (mm) for the 11 years before 2011, was 705,5 mm but for the six years after 2011, was 701 mm. Both are marginally below the 18-year period's average rainfall of 722 mm. In addition, we can compare Figure 28 and Figure 20 for the differences between the Lines of Best Fit between these two periods.

A second difference is that there are now eight years with below 722 mm rainfall in this 11-year period before 2011. The total rainfall for those eight years with below 722 mm per annum, is 4 533 mm and their average is 566 mm, in comparison to the four years after 2011, that had a total of 2 416 mm or an average of 604 mm that is below the 722 mm average. The differences are presented as follows (Fig 29):

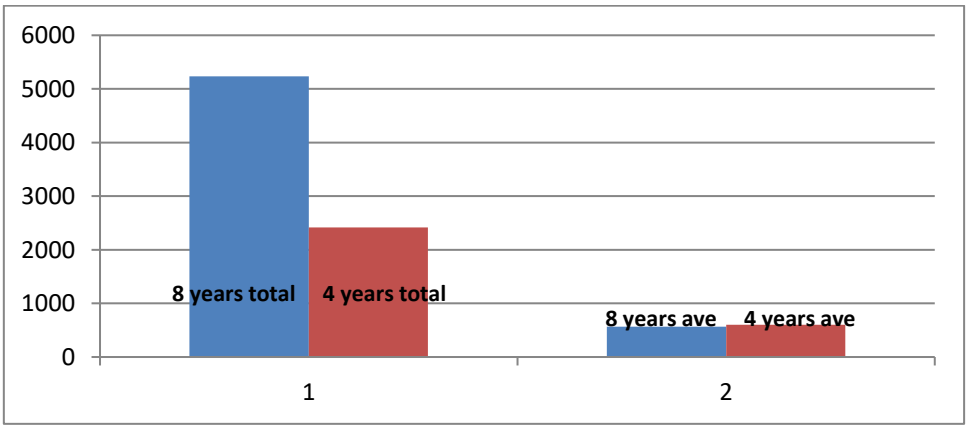

Figure 29. Comparisons between 8 and 4 years with below 722 mm rainfall.

Thirdly, in P2 were three consecutive 2-year periods with below average off 722 mm rainfall, but in P1 are only two (Fig. 7, Fig. 11, Fig. 26 and Fig. 27).

The suggestion is also that this 18-year period is too short to make meaningful observations about apparent 5–7 year rain cycle theories in general. This hypothetical basis should still be considered for NVF. The suggestion is furthermore that Figure 4 supports the perception that 5–7 year dry-wet cycles have not been established for NVF.

Table 2 reflects the difference in rainfall (mm) in comparison to the previous year in chronological order.

5. A comparison between P1 and P2

5.1 Total and average rainfall (mm) for P1 (6 509 mm) and P2 (6 502 mm)

The total rainfall over the 18-year period was 13 011 mm (Table 1 and Table 2); the average rainfall for the period was 722 mm (Fig. 7, Fig. 8, Fig. 11 and Fig. 13) and the difference between the totals for P1 and P2 was 7 mm and presented in Table 1 and Figure 9.

5.2 *Above* average rainfall (of six years) for combined P1 and P2

When the annual rainfall for the six years (three in P1 and three in P2) that had above average rainfall of the study period (of 722 mm) is isolated from the rest of the 18-year period and compared, then that comparison, is presented in Figure 13.

The average rainfall for these six years was 892 mm compared to the 18-years average of 722 mm. Figure 14 shows this difference of averages.

5.3 *Total* rainfall for P1's three years vs P2's three years with *above* average rainfall

The total rainfall for the three years in P1 that had above average rainfall of 722 mm was 2 524 mm and 2 829 mm for the three years in P2 with above average rainfall. The comparison is shown below in Figure 30:

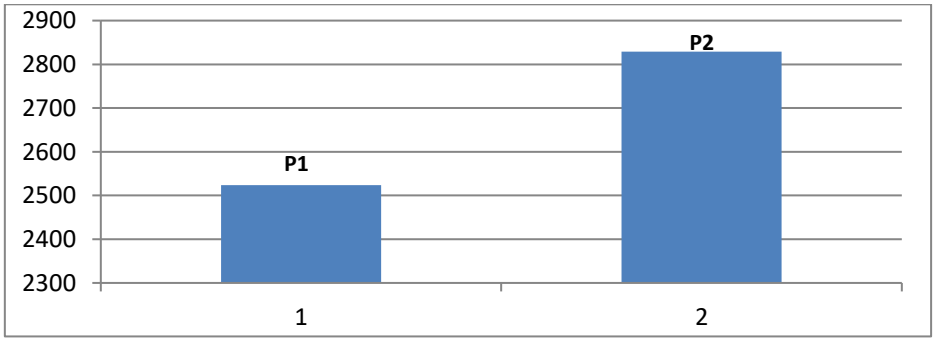

Figure 30. Total rainfall for three years with above rainfall in P1 and total for three years in P2 with above average rainfall.

The Line of Best Fit for P1 (Fig. 31) and that of P2 (Fig. 21) are similar, regardless of the differences between the annual rainfall fluctuations.

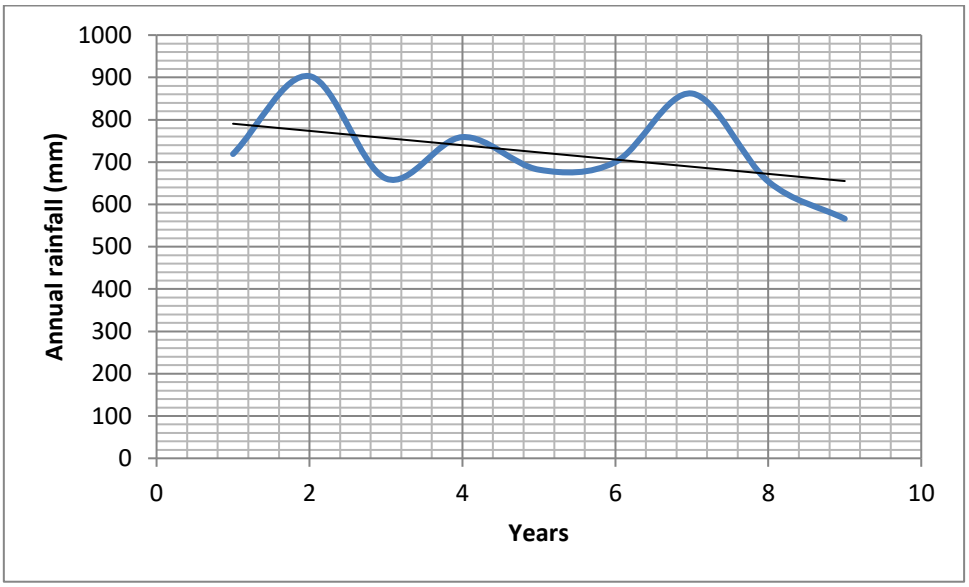

Figure 31. Linear Line of Best Fit for P1.

They are both part of the Line of Best Fit for the entire 18-year period in Figure 2 but it shows a declining trend of approximately <70 mm for the study period.

The constant gradient shown by the Line of Best Fit (Fig. 2) for the 18-year period, and the general trend shown by the cumulative annual total rainfall (mm) in Figure 33, cannot show any meaningful or sustainable change in the rainfall pattern for NVF over the study period.

5.4 *Below* average rainfall (for 12 years) for combined P1 and P2

When the annual rainfall for the 12 years (six years in P1 and six years in P2) that had below average rainfall (of 722 mm) is isolated from the rest of the 18-year period and compared, then that comparison, is presented in Figure 15.

The average rainfall for these 12 years was 637 mm compared to the 18-years average of 722 mm. Figure 15 shows this difference of averages.

5.5 *Total* rainfall of P1's six years vs P2's six years with *below* average rainfall

The total rainfall for the six years in P1 that had below average rainfall of 722 mm was 3 985 mm and 3 664 mm for the six years in P2 with below average rainfall. The comparison is shown below in Figure 32.

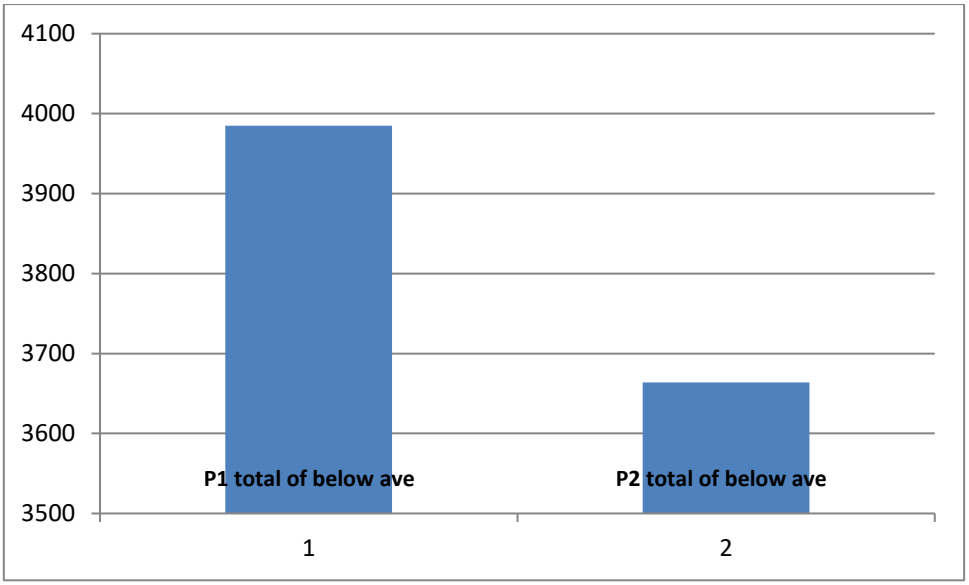

Figure 32. P1 and P2 totals of below average of 722 mm compared.

Despite all above variances and comparisons, still cannot suggest sustainable long-term rainfall behavioral change.

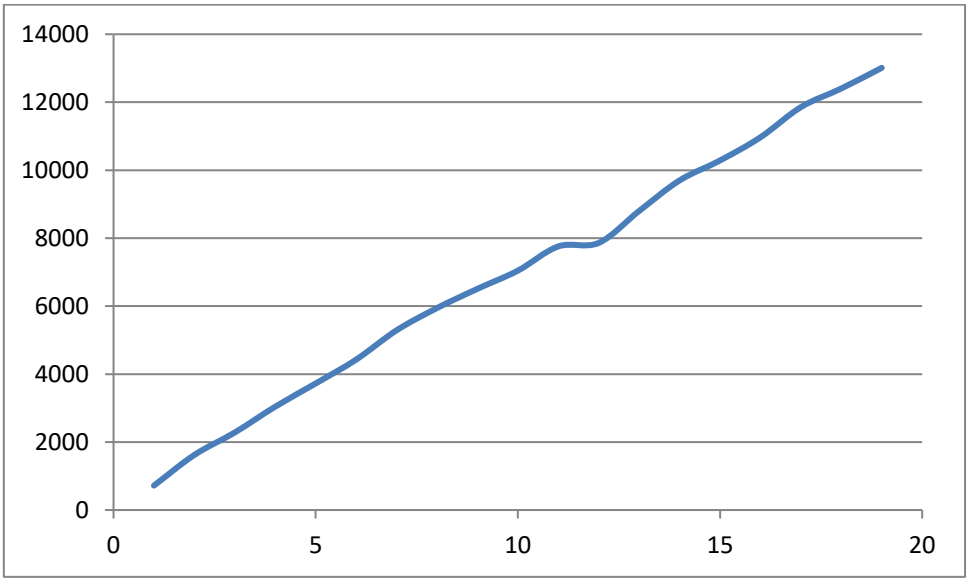

Figure 33. Cumulative total annual rainfall (mm) for NVF over an 18-year period.

This study (Part I) has not analysed sub-annual data sets but instead, has mainly focused on total and average annual rainfall (mm) results.

As a result, despite the above, Figure 34 shows the average monthly rainfall (mm) across the four seasons in South Africa for NVF, will be the starting point for Part II.

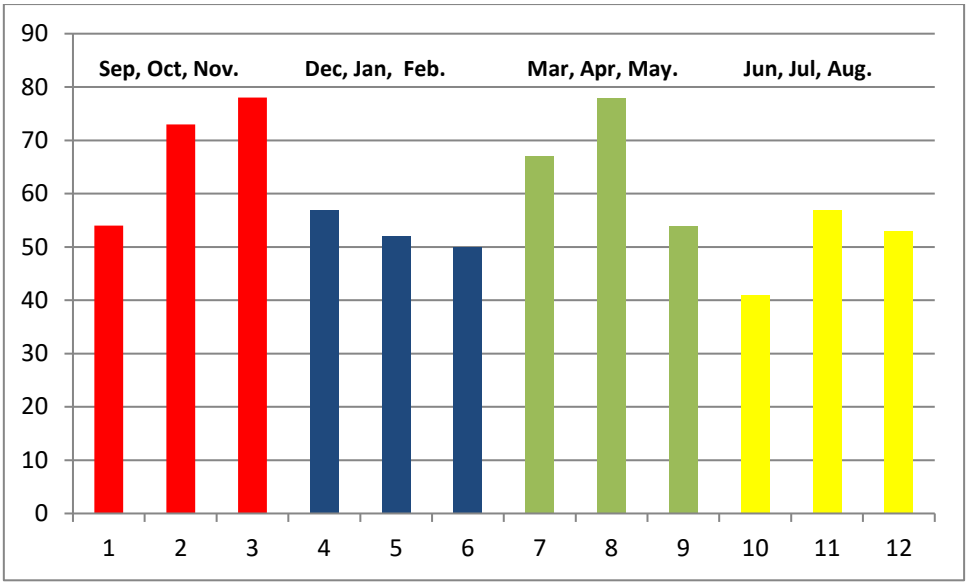

Figure 34. Average rainfall (mm) per month across the four seasons in South Africa for NVF.
Key: Red = Spring
Blue = Summer
Green = Autumn
Yellow = Winter

Again, much understanding is based on the comparative method. For instance, Figure 7 best shows the need to investigate the possible presence of a short-term patterns of declining or increasing trends over 3-year rainfall periods.

For the sake of clarity: consecutive 2-year or consecutive 3-year (etc.) periods (C2-yp of C3-yp), are periods following after the other with higher or lower rainfall (mm). For instance, in Figure 11, 2004, 2005 and 2006 are considered a C3-yp since for three years the rainfall increased year on year, and 2011, 2012 and 2013 are also considered a C3-yp but with declining rainfall (mm) for three years. Lastly, 2006, 2007, 2008 and 2009 represent a C4-yp with declining rainfall (mm).

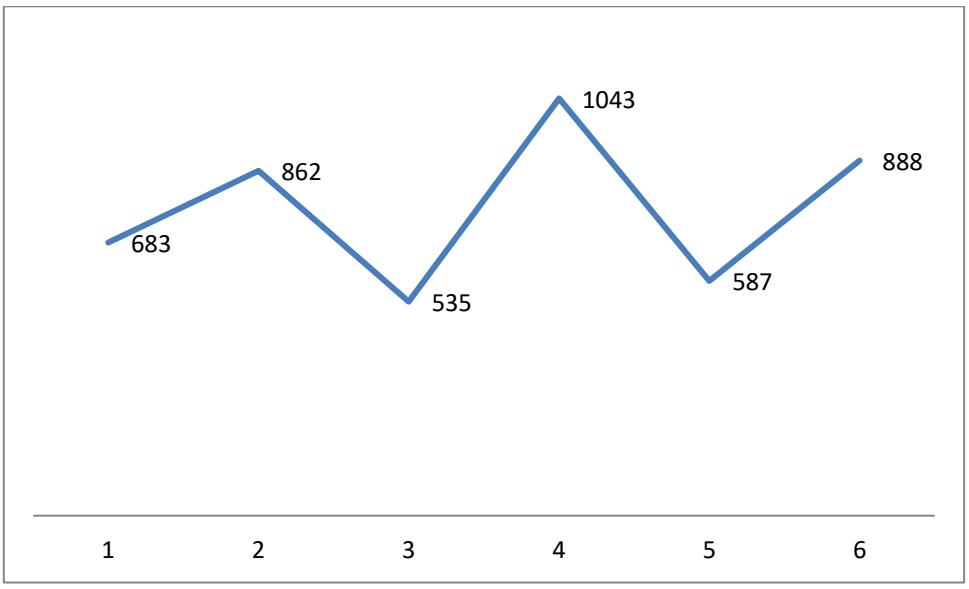

Figure 34. Consecutive 3-years rainfall periods at NVF**.**

Conclusion

Studies in near-future and far-future predictions (SAWS 2017: 3) and analyses of climate change are fertile grounds also for studies in enviro-history where the scope of investigation can vary from micro- to global-levels of analysis and research fields. The implication is that the historical divide between those with the

> 'widely held opinion that history, in contradistinction to the so-called physical sciences, is concerned with the *description of particular events* of the past rather than with the *search for general laws* which might govern those events' (Hempel 1971: 231), have been reduced (emphasis added).

This kind of *problématique* that surrounded the climate change debate seems to have also been arrested in the sense that changes in climate are accepted as they present themselves differently in different parts of the world. Environmental humanities are well-placed to contribute much to the construction of bridges for interdisciplinary knowledge transfer.

Historical rainfall data, as in the case of NVF, and, according to SAWS (2017: 5), is closely related to '[c]limate change projections [that] are based on probable future outcomes, and are therefore associated with uncertainties', suffer from the same limitations. As an example: the probability of a repeat period of 0,05% that the 2011 HRE flood of 18 years of equal or greater magnitude will occur in any given year, will only be borne out by nature and history. The mere fact that consecutive 2-year periods appear infrequently at NVF, is an appropriate example.

Since rainfall claims an important position in the climatic and environmental studies of any region, it is impossible to maintain healthy ecosystems (Chakraborty 2014: 6225) without adequate water levels in the Kap River. All life forms e.g. plants, insects, birds etc. are all compromised without sustainable water levels. The reason is not complicated:

> 'water is life' and the 'concept of sustainability demands that only such a quantity of energy and raw materials be used as will be restored through natural process during the same period' (Thommen 2013:7), needs to be kept in balance.

Despite the value of Lines of Best Fit as applied a few times in this study, and based on the extent of compromises, rainfall comparisons are, but long-term predictions on these figure are not, advisable. For instance, the year with the highest rainfall (2011), was not necessarily associated with floods. Catastrophic impacts of the water regime have immediate short term consequences on e.g. fish and frogs, hence a general understanding of the characteristics of rainfall (amount, duration, distribution

frequency and intensity) are just a few factors that could mitigate the destruction of all rain-dependent life-forms. The hydrological processes at the catchment of rivers are independent of administrative and political limitations yet important in understanding probabilistic river discharge forecasts (Pappenberger *et al.* 2013: 4).

For a period six years, the low-water bridge was left unrepaired. That is a typical example of 'a low adaptive capacity' (de Sousa Pinto 2015: 2) of the accountable managing community of the KRNR to have had the bridge replaced or repaired in a reasonable time. De Sousa Pinto (2015: 3) also referred in his study to 'increasing evidence from observed climate trends that globally extreme precipitation events are becoming more frequent and more intense', meaning that 'the nature of climate extremes is changing'. For these and other reasons, the appropriate allocation of life-dependent scarce resources, are non-negotiable. The socio-economic and geo-political imperatives of the nature of hydro-politics dictate that local rainfall history be undertaken.

The fast-growing body of rain-related research shows that despite mega-scale models and levels of explanation, 'local means global and global means local'. The one approach is not more important than the other and the citizenry needs to be kept informed whether sustainable changes in rainfall patterns are known or not.

Specific observations regarding the rainfall at NVF in the immediate vicinity of the KRNR are worth paying attention to. The Line of Best Fit suggests a decline of approximately <70 mm over 18 years (Fig. 2). The total rainfall for P1 and P2 differed by only 7 mm (Fig. 9) despite the noticeable differences as portrayed by Figure 3 and Figure 8. About 66% of the 18-year period (or 12 years) had below average rainfall of 722 mm indicating that the number of dry years was twice as many as wet years. The six years with above average rainfall (Fig. 13) contributed much to 'normalize' the average rainfall over 18 years. There was only one period with four consecutive years with declining rainfall in comparison to the previous, and the 'ups' and 'downs' in P2 appear to have been more consistent (regular) than in P1 (Fig. 15).There is no similarity in the rainfall during the years following the year with the highest rainfall in comparison to the same period prior to that year (Fig. 7). No resemblance between the three years in P1 and thee for P2 in above average rainfall became clear when compared to those with below average rainfall. An 18-year period is too short to make meaningful comments about near-future and far-future rainfall predictions. The probability for a return period such as 2011 is low. What does seem more likely, is that the concept of 'consecutive periods' could suggest short term patters as shown in Figure 34.

Much site-specific rainfall research in future is required to unearth sub-annual levels of analyses at NVF and the immediate KRNR area.

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